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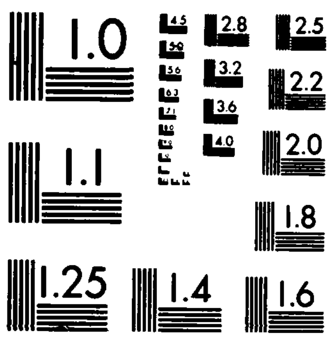

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FEASIBILITY OF MEASURING PRODUCTIVITY IMPROVEMENTS IN THE TACTICAL AIR FORCE'S ACCOUNTING AND FINANCE OFFICES USING THE DATA ENVELOPMENT ANALYSIS (DEA) MODEL

THESIS

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

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Master of Science in Systems Management

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Captain, USAF

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Table of Contents

Page

List of Figures

List of Tables

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Abstract

The objective of this research was to measure the productivity of the Tactical Air Command's ~~(TAC)~~ Accounting and Finance Offices (AFOs) for calendar years 1983-1985. Two separate approaches, both using a methodology called Data Envelopment Analysis (DEA) as their base, were used to measure productivity changes over this period. Both approaches (window analyses and program versus managerial efficiency) used a two input, seven output DEA model for the analyses.

The window analyses approach is analogous to smoothing techniques used in econometrics and involved subdividing the annual data into quarterly data and creating moving windows consisting of three quarters of data for each AFO. The first three quarters of data were initially evaluated for all 18 AFOs and then subsequent analyses were performed by dropping the first quarter's data and adding the next (fourth quarter's data). This process of dropping and adding quarterly data was continued until each group of three quarters of data were analyzed, forming a moving "window" of each quarter so that changes over time could be detected.

The program versus managerial approach eliminated managerial inefficiencies for each year and then compared

each year's activity (=program) for productivity changes that were programmatic. To implement this approach each year's data were treated as a unique program and analyzed separately using DEA. The DEA results were then used to "adjust" the AFOs found to be inefficient, resulting in all units for that year becoming efficient. All three programs were then analyzed together using the DEA model. These results were then reviewed for shifts in productivity between programs (years).

Productivity changes were checked through the use of regression analyses. Even though each approach showed signs of productivity increases, the corresponding statistical tests failed to provide conclusive evidence to support an actual increase during this period.

FEASIBILITY OF MEASURING PRODUCTIVITY IMPROVEMENTS IN THE TACTICAL AIR FORCE'S ACCOUNTING AND FINANCE OFFICES USING THE DATA ENVELOPMENT ANALYSIS (DEA) MODEL

I. Introduction

General Issue

The Federal Productivity Measurement Program, established in 1973, requires all segments of the federal government to submit productivity data on an annual basis. These data are compiled into indices for the Federal Productivity Report submitted to the President and the Congress annually (16:1; 19:1). The Air Force Management Engineering Agency (AFMEA) is tasked with gathering, analyzing, and submitting these data for the United States Air Force (USAF). While helpful at monitoring productivity at an overall USAF functional level and fulfilling this annual requirement, this data collection exercise has been of little benefit to major command or base level functional managers.

Statement of the Problem

AFMEA is responsible for directing the development of productivity measures throughout the USAF. It currently fulfills this responsibility by working with functional

managers in establishing reporting systems that are both useful to the functional managers for managing their operation and to AFMEA in fulfilling the annual submission of productivity data requirement for the Federal Productivity Measurement Program (18:6). AFMEA has been successful in developing productivity measures and reporting systems at the aggregate level for inclusion in the annual Federal Productivity Report, but they have experienced limited success in establishing productivity measures which major command or base level functional managers can benefit from.

One of the primary reasons for AFMEA's lack of success at implementing productivity indices for major air command and base level managers lies in the inherent problems of using indices to measure productivity within the public sector. Unlike the private sector, the public sector is not profit motivated and subject to market-like conditions. Therefore, it is faced with the complexing question of how to value or compare its various outputs. The result has been to evaluate productivity achievements with multiple indices computed from multiple inputs and multiple outputs.

There are two limitations to the index approach of measuring productivity. First, this process often requires computing multiple indices instead of only one or two and therefore is not easy and convenient to use. For example, in 1977 when AFMEA and the Air Force Accounting and Finance

Center (AFAFC) initially developed the productivity measures for the accounting and finance network, they discovered it would require approximately 3000 indexes to properly evaluate all the base level accounting and finance offices. As a result, the decision was made to accumulate the indexes only at the command level, still requiring 405 indices (1:A1-A3). A later decision was made to reduce this even further by computing only 11 indexes at the aggregate Air Force level.

Another limitation is in the interpretation of these indices once they are computed. Indices may indicate an organization is strong in one area but weak in another, while another organization's strengths and weaknesses may be just the reverse. Choosing one of the organizations as the best becomes a subjective decision. As the number of organizations and indices increase, this process becomes even more difficult. One way to reduce this uncertainty is to set weights to the indices. However, this process of quantifying various outputs can become quite complex and subject to challenge.

These limitations have resulted in AFMEA concentrating on only the macro level of productivity measurement at the aggregate USAF level. This has left major air command and base level functional managers with little means to measure any progress they might achieve in introducing new programs and ideas toward productivity enhancement.

With the increased emphasis in recent months on reducing the multi-billion dollar federal deficits (e.g., Balanced Budget and Emergency Deficit Control Act), invariably there will be even more pressure to increase productivity than in the past. In order to succeed in developing a total productivity program, more emphasis needs to be placed on measuring productivity at all levels.

This thesis pursues this effort of finding a better way to measure productivity that can benefit major air command and base level functional managers. It does this by testing the feasibility of using a relatively new technology developed by A. Charnes, W. W. Cooper, and E. Rhodes (11) called Data Envelopment Analysis (DEA) to measure the productivity of the Tactical Air Command's (TAC) Accounting and Finance Offices over a three-year period (1983 through 1985).

The DEA model is used in this thesis to test for changes in productivity within the TAC Accounting and Finance Offices (AFOs) over a three-year period (1983 through 1985). This is accomplished in two ways. The first approach is known as "window analyses." This technique was used in Bowlin (6) and in Charnes, Clark, Cooper, and Golany (9) after having been introduced in Charnes, Cooper, Divine, Klopp, and Stutz (8). It introduces more degrees of freedom into an analysis by subdividing each organization's activities into smaller time segments such

as months or quarters and identifying each new unit as a differently dated activity. For example, for this thesis annual data is subdivided into quarterly data, resulting in 12 quarterly units of data for each organization versus three annual units.

Following this approach, the first three subdivisions are initially evaluated for all 18 AFOs and then subsequent analyses are performed by dropping the first quarter's data and adding the next (i.e. fourth quarter's data). This process of dropping and adding a unit is continued until each group of three quarters of data are analyzed, forming a moving "window" of each subunit so that changes over time can be detected.

The second approach is one developed by Charnes, Cooper and Rhodes (CCR) in their work with Program Follow Through (10). This approach separates inefficiencies into two separate types: program and managerial. "Program inefficiency" is an internal type inefficiency in that it is an inherent part of or internal to the program. In other words, if management executes a program perfectly, as it is designed, "program inefficiencies" will still occur because they are built into the program. "Managerial inefficiencies," on the other hand, are external-type inefficiencies. These inefficiencies occur because of management's inability to properly execute a program. The CCR approach will be used to disentangle "managerial

inefficiencies" from any "program inefficiencies" in an attempt to pinpoint productivity changes as a result of program (i.e. accounting and finance office operations) enhancements over time (1983 through 1985).

To implement the program versus managerial approach <u>each year's</u> data for the 18 TAC AFOs is treated as a separate program and analyzed separately using DEA. Then the DEA results are used to "adjust" the data of the AFOs found to be inefficient, resulting in all units for that year becoming efficient. The amounts added to the inefficient units correspond to the managerial inefficiencies present in these AFOs for that year since all AFOs would be operating under the same guidance or program for that year. These adjustments will place all units on the efficiency frontier for that year (program). Once all the managerial inefficiencies have been removed for all three programs, the three programs (= years) are aggregated and analyzed again using the DEA model. These results are then reviewed to see if the 1985 AFOs are more efficient than the 1984 AFOs or the 1983 AFOs. If the later year's AFOs indicate a higher efficiency, then this indicates productivity has increased over time.

Research Objectives

The objectives of this thesis are to:

1. Define the criteria for selecting the inputs and outputs for the DEA model.

2. Use this criteria to select the appropriate inputs and outputs that best measure productivity within the TAC Accounting and Finance Offices.

3. Develop DEA models for measuring the productivity of the TAC Accounting and Finance Offices.

4. Use the results of the models to test for productivity changes over time.

5. Make recommendations for further testing and using DEA to measure productivity for command and base level accounting and finance offices.

Scope

This research is limited to accounting and finance work load data for 18 TAC bases over a three-year period, calendar years 1983 through 1985. Accounting and finance data were chosen for this research for two reasons: (1) all accounting and finance offices are required to submit a monthly report, RCS: HAF-ACF(M) 7104, Report of Accounting and Finance Activities (1:1), summarizing their monthly work load data which can be easily adapted to this research; and (2) the author's personal interest in this area, having worked as an Accounting and Finance Officer for six years. TAC Accounting and Finance Offices were selected because TAC is the only command that possesses calendar year 1983 through 1985 data, permitting a three-year analysis. Consideration was also given to TAC's interest and achievements in productivity enhancement.

This command boasted an 80 percent increase in productivity between 1978 and 1984 measured by flight sortie rates. This was possible through sweeping changes under the dynamic leadership of General Creech, the Tactical Air Force Commander during this six-year period (23:14).

This chapter has established the foundation for the remainder of the thesis. The next chapter contains a literature review on productivity. It includes a historical background of the concern over decreasing productivity within the U.S. and the Department of Defense, definition of productivity, and a discussion on the various methods of measuring productivity.

Chapter III, the methodology chapter, has three sections. Sections one and two fulfill the first two research objectives dealing with establishing the criteria for and selecting the inputs and outputs to be used in the DEA model. The third section describes the DEA model, along with the DEA methods first introduced in this chapter.

Chapter IV, Analysis and Results, contains three sections. The first section discusses the computer resources used. The next section displays the results and analysis of the DEA model using the window analysis approach. The final section describes the results and analysis of the DEA model using the program managerial versus efficiency approach.

Chapter V addresses the conclusions from this research and makes recommendations for further research.

II. Literature Review

This chapter contains a review of literature on productivity with specific emphasis on ways to measure it. The first section presents various ways of defining and measuring productivity. The second section explains why productivity has declined in the private sector of the economy over the past twenty years and some of the impacts of that decline. The third section explains the development of the productivity program within the Department of Defense. The fourth section describes various methods of measuring productivity, including their strengths and weaknesses.

Definition of Productivity

The literature reveals no one accepted definition for productivity. Productivity means different things to different people, depending on the context and purpose in which it is being used. Ali Dogramaci defines productivity as "a measure of how well people are responding to the understood objectives and accepted goals of an enterprise" (27:149). David J. Sumath describes productivity as follows: "Productivity is concerned with the efficient utilization of resources (inputs) in producing goods and/or services (output)" (34:4). James L. Price

describes productivity as "the ratio of output to input in an organization" (30:205). Paul Mali describes it as,

> . . . the measure of how well resources are brought together in organizations and utilized for accomplishing a set of results. Productivity is reaching the highest level of performance with the least expenditure of resources. (26:6)

All these definitions focus on the production of output through the efficient use of resources. The definition this author prefers and which is used throughout this thesis is taken from the Statement by the Research and Policy Committee for Economic Development. They describe productivity as follows:

> Productivity measures the relationship between outputs (the amounts of goods and services produced) and inputs (the quantities of labor, capital, and material resources used to produce the outputs). When the same amount of input produces larger quantities of goods and services than before, or when the same amount of output is produced with smaller quantities of inputs, productivity has increased. (31:9)

This description of productivity can be illustrated through the following example:

Assume an organization used 25 units of inputs (i.e. labor, capital, etc.) to produce 20 units of output. Their productivity level would be 20/25 (outputs/inputs) or 0.8. If this same organization is able to increase this output from 20 units to 25 units through a new technological change or better use of their resources without increasing the number of units of input, productivity would clearly be increased to 25/25 or 1.0, an increase of 25 percent. Alternatively, if the organization is able to

produce the original 20 units of output by using only 20 units of inputs versus 25 units, productivity would also increase to 1.0 (20/20). A third way of increasing productivity would be through a combination of increasing both inputs and outputs, whereby the marginal ratio increase of outputs over inputs is greater than the original productivity level. For example, if inputs increased by 25 (from 25 to 50) and outputs increased by 25 (from 20 to 45), the marginal rate of productivity increase would be 25/25 or 1.0 (which exceeds the original productivity level of 0.8) and the overall productivity of the organization would become 45/50 or 0.9, an increase in productivity of 12.5 percent.

There are basically two ratios used in measuring productivity: labor productivity and total-factor productivity (TFP) (24:3). The labor productivity ratio is a measure of output per worker or per hour worked. It is calculated by dividing the total amount of output produced by the total amount of labor (number of workers or hours) used in producing the output. This measurement dates all the way back to the nineteenth century when the first productivity estimates were prepared by the Bureau of Labor. It remained the only type used until World War II (24:2). It is still the most common form of productivity measurement and the most significant determinant in a nation's

standard of living. Labor productivity is the measurement that is used in this thesis.

TFP differs from labor productivity in that it considers all inputs consumed in the production of outputs instead of just labor. It was first introduced in the United States by George Stigler in 1947 and has subsequently been developed by various economists since then (24:3). TFP is much more difficult to estimate but is very helpful in determining the underlying causes for changes in labor productivity. It is the measurement generally published in the measurement of productivity within the economy, although it is generally accompanied by labor productivity.

Productivity Decline in the United States

The concern over productivity evolved in the 1960s when productivity levels in the United States industrial base began to slow down substantially. This resulted in two problems for the U.S.: (1) the slow down in the productivity growth rate in the U.S. compared with prior years; and (2) a much lower productivity rate throughout the past two decades in comparison with rates in Japan, Italy, France, Sweden, West Germany and other industrial countries (31:8).

The productivity growth rate (using TFP) first began to decline noticeably in 1966. The 18 years prior to

1966, the productivity rate grew at an average annual rate of 2.9 percent. Over the next ten years, 1966 to 1976, the productivity rate averaged 1.4 percent, less than half of what it was (25:6). The productivity rate even fell below a 1 percent growth rate for a number of years beginning in 1973.

While the productivity rate of other industrial countries has also fallen, they have remained significantly higher than the U.S. rate. For example, between 1960 and 1979, the U.S. lagged behind Italy, Japan, Sweden, Canada, United Kingdom, France and West Germany in average annual rate of productivity growth. Japan, the leader in productivity growth during this period, averaged nearly 8 percent annual growth, more than triple the rate for the U.S. over the same period (31:15).

Reasons for Productivity Decline. A number of reasons have been cited for the lagging productivity growth within the United States. Many believe that the decline in capital formation played a major part in the productivity slowdown (2:36). During the most substantial decline in productivity growth after 1973, the rate of capital formation actually increased compared with the period prior to 1973, but the effects of these increases were significantly reduced because of a subsequent accelerating growth in employment. Capital increases generally result in higher productivity growth than labor increases. Wide disparities

exist in different studies on capital formation during this time depending on which definition of productivity or which data source was used (2:36).

A second reason for productivity decline was the change in the composition of the labor force. As noted above, not only was there a sharp increase in the labor force but much of this increase was made up of teenagers and women entering the labor force for the first time (2:41). These two groups of workers lacked the experience of older workers leaving the labor force and, therefore, their productivity was less, reducing the overall productivity rate of labor (2:39).

The dramatic increase in the price of oil and subsequent increase in the price of energy in the early 1970s is noted as a third reason for a decline in productivity growth. Because of the high cost of energy, firms slowed down their investments in capital, relying more on labor increases.

A decline in research and development (R&D) is cited as a fourth reason for productivity decline. Expenditures in R&D normally result in technological advances in more inexpensive ways of producing goods already in production or through the introduction of new products (2:43).

A fifth reason for a declining productivity rate is the composition of the output. This is an area that receives some disagreement among various authors. The

composition of output deals with the changes in the products produced by the economy over time. Recent shifts between goods and services production have impacted the capital to labor ratio, directly affecting the productivity rate (2:44).

A sixth reason for productivity decline is government regulation. Increased requirements placed on businesses by the government such as pollution control or reporting procedures, divert resources from inputs that would otherwise be used in producing outputs, resulting in decreased productivity. Taxes on industry also impact productivity by decreasing the amount of expenditures available for inputs (2:46).

The final reason for productivity decline, cyclical factors, is considered a temporary problem. Productivity growth is known to decline during the downturn of a business cycle or during a recession, as was prevalent in the 1970s. On the other hand, productivity tends to rise during periods of economic recovery (2:47).

These seven factors are the most prevalent ones found in a number of studies as reviewed by William J. Baumol and Kenneth McLennan (2). Recognizing the factors leading to productivity decline is one important part of establishing ways to reverse this unfavorable trend.

<u>The Impact from Declining Productivity</u>. The impact of this loss in productivity growth was highlighted in the

1983 Statement by the Research and Policy Committee of the Committee for Economic Development,

> . . . if the U.S. growth rate continues to lag substantially behind that of other industrial countries, and if such differences continue for a protracted period, our relative standard of living must decline. (31:8)

Few people would disagree that the rate of productivity growth for an industrial nation is directly related to its standard of living. Productivity advancements are the chief reason for the increased wages experienced by American workers over the years. Increased productivity, being the key to economic progress, is also an essential underpinning of the nation's security (31:1).

Declining productivity within the U.S. has resulted in its loss of a significant portion of foreign market shares as well as within its own domestic market. A few years ago, foreign companies held only a minor share of the U.S. market for mass produced items. Today, however, foreign producers hold a large share of the automobile, electronic equipment, bicycle, motorcycle, small appliance and camera market within the U.S. (31:25). This large influx of imports into the U.S. over the past few years has resulted in large trade deficits for the U.S. and a reversal of its role as a creditor nation to a debtor nation (21:20).

Quality, an important component of productivity, has increased significantly in the products of foreign manufacturers. One study found that

> 96 percent of [Japan's] automobiles leave the production line in fit shape for delivery, versus 75 percent of ours. American rent-a-car companies report that cars made in the United States require two to three times more servicing than comparable Japanese cars. (31:43)

This is just one example of the differences in quality between U.S. products and its foreign competitors and does not appear to be widespread. These secluded reports, however, further demonstrate the need for increased productivity in U.S. manufacturing firms if they want to maintain a dominant share of the domestic market.

Productivity in the Department of Defense (DOD)

Productivity is just as much a concern within DOD as in the private sector. Only in the past decade or so, however, has there been any attempts made in measuring productivity within DOD, partially because of the problems in its measurement with indices as discussed in Chapter I.

Recognizing the need for measuring productivity within DOD, the permanent Federal Productivity Measurement Program was established in 1973. This program requires the annual submission of productivity data from all federal government departments and agencies. This data is consolidated and distributed annually to the President and the Congress (18:11). The guidelines for the DOD Productivity Measure Program are spelled out in DOD Directive 5010.31, DOD Productivity Program (15) and DOD Instruction 5010.34, Productivity Enhancement, Measurement, and Evaluation--

Operating Guidelines and Reporting Instructions (16). The taskings for development of the DOD program within the USAF are included in AF Regulation 25-3, Air Force Productivity Program. AF Regulation 25-3 places emphasis on focusing on "total factor productivity enhancement" instead of just improving the efficiency and effectiveness of labor (18:2). Concentrating on finding cost beneficial projects that will enhance TFP, the Air Force has designed a multitude of programs designed toward this effort, normally approved through budgetary channels (18:3). Examples of these programs are the Productivity Investment Fund (PIF) Program, Fast Payback Capital Investment Program (FASCAP), and Component Sponsored Investment Program (CSIP). These programs are all designed to compete for special funds set aside by the Office of the Secretary of Defense for productivity enhancement capital investments (PECIs) in equipment and facilities. To qualify each request must demonstrate a savings to the Air Force over a designated period of time. This net savings equates to producing the same amount of output (or possibly even more output) with less input (less capital cost) hence increased productivity.

Most recently the President issued an Executive Order entitled Productivity Improvement Program for the Federal Government. The goal of this program is "to improve the quality and timeliness of service to the public, and to achieve a 20 percent productivity increase in

appropriate functions by 1992" (29:7041). This goal clearly demonstrates the necessity for a well established productivity program and the ability to measure productivity at each level throughout DOD so that progress toward this goal can be properly monitored.

The Air Force accounting and finance network has responded to this productivity challenge in recent years by developing various initiatives toward enhancing productivity within the AFOs. According to Lt Col James Chittick, Director of Network Operations at AFAFC (12) and CMSgt John Rand, Superintendent of the Management Division at Headquarters TAC/ACFQ (32), there were many accounting and finance initiatives that should have impacted the productivity of the TAC AFOs during the three-year period (1983 through 1985) covered by this research.

For example, the JUMPS Data Collection System was implemented in all Military Pay Subject Matter Areas (SMAs) throughout the USAF between January 1983 and September 1985. This system allows Military Pay personnel to enter pay and leave transactions directly to AFAFC on a daily basis. This has eliminated the antiquated process of punching, editing, and transmitting keypunch cards for each of these many transactions. This has significantly reduced the work load of the Military Pay SMA.

Another improvement was the implementation of Flat Rate Per Diem for military and civilian travelers. This

new system has simplified the many calculations required to compute a travel voucher and the number of inquires from these travelers.

Another productivity enhancement unique to the TAC AFOs was the implementation of the "PEERS" program in 1985. This program places various organizations within TAC, such as the AFOs, into head-to-head competition with their peers. A series of measurements are used to rank order these organizations on a monthly basis. Organizations ranking low in any one measurement within the command are encouraged to contact the offices ranking high in that measurement and inquire on how they might improve their operations in that area. This continuous cross-feed between individual bases helps these organizations acquire new ways of getting their job done more effectively and efficiently, hence productivity is increased.

Methods for Measuring Productivity

There are many ways to measure productivity within an organization. Three ways are described in this section along with their individual advantages and disadvantages. First ratio analysis is described, followed by regression analysis, and finally Data Envelopment Analysis.

Ratio Analysis. Ratio analysis is probably the most widely used and understood method for measuring productivity. It is a process by which one or more outputs

of an organization is (are) divided by one or more inputs consumed in the production of the output(s). These ratios, once computed, are compared to some established standard, previously calculated ratios, or comparable ratios of other organizations to determine if goals or objectives are being attained. Two such ratios used to measure the nation's productivity, labor productivity and TFP, were introduced in the first section of this chapter. Labor productivity differs from TFP in that it uses only one input, labor, instead of all the inputs that are consumed in producing an output. Labor productivity is an example of a partial ratio while TFP is an example of a total factor ratio.

Partial ratios are frequently computed in an organization that consists of multiple inputs and outputs, enabling it to hone in on the progress of one certain area. For example, a partial ratio might be the number of pages typed by a typist in an eight-hour day. The ratios of two typists assigned to two organizations can easily be computed and compared to determine which is more productive. The results of partial ratios, however, can be very misleading. They fail to consider other inputs that might have an effect on the output being measured. For example, the two typists mentioned above may have two significantly different types of typewriters or word processors. One typist might have to constantly answer the telephone or perform other duties. Without knowing the impact other

inputs have on computing partial ratios, a wrong conclusion can easily be made. A total factor ratio, on the other hand, considers all the inputs used in the production of an output. It does not, however, distinguish as to which input is responsible for any changes in a given output, nor is it easy to combine the noncommensurate factors into a total factor.

For organizations consisting of multiple inputs and outputs, different partial ratios are normally computed for the various outputs produced. While these ratios for two like organizations can be compared one for one, an overall productivity assessment of the organizations is very difficult to compute using ratio analysis. As mentioned in Chapter I, one method of getting around this is to assign weights to each ratio using some logical method. For many organizations these subjective weights can be very controversial, depending on the various opinions of management. One set of weights may make an organization look good while another set of weights may make another look favorable.

Least-squares Regression Analysis. A second method, least-squares regression analysis, can be used for measuring the relative productivity between organizations by using one or more independent variable(s) and one dependent variable. The independent variables can be either inputs or outputs. Regression analysis formulates an averaging

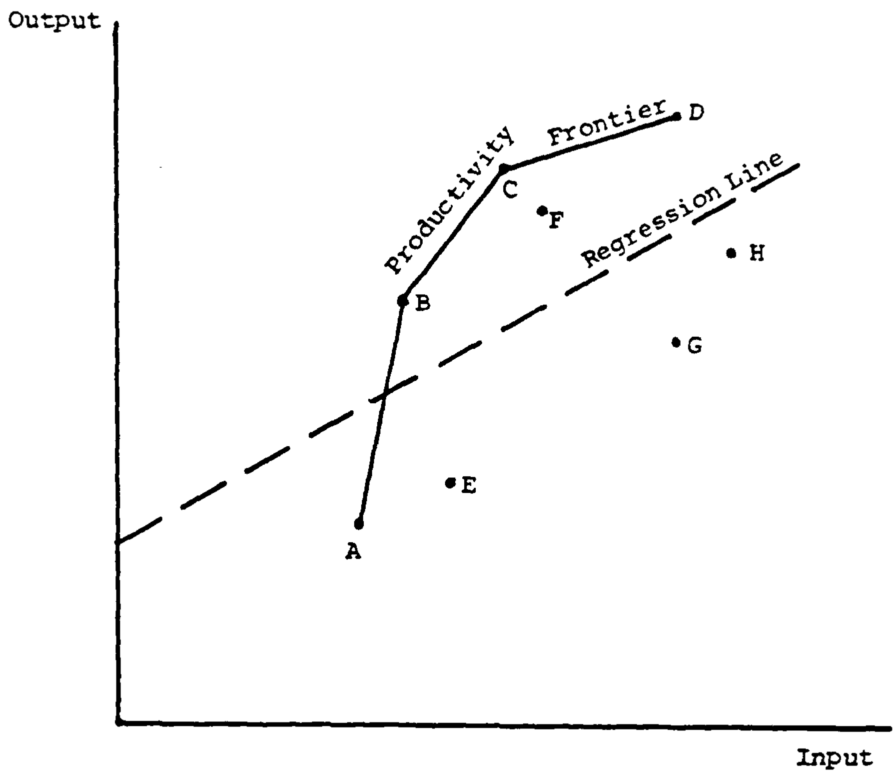


Fig. 1. Comparison of DEA and Regression Analysis

relationship based on the designated inputs and outputs. Figure 1 demonstrates a simple one input, one output example of least-squares-best-fit regression. The regression line is the "best fit" between the points (observations) A through H. This line is created by minimizing the squared deviations from the mean of the inputs and the mean of the outputs. When two independent variables are used, a plane is formed instead of a line and can be drawn using a three-dimensional graph. While more than two independent variables can be mathematically computed, a graph of the results becomes impossible to draw. While

regression analysis has the ability to consider multiple independent variables (e.g., inputs) simultaneously, it is limited by its ability to consider only one dependent variable (e.g., output) at a time. This results in the similar problem experienced with ratio analysis in that productivity is only partially measured by each output. Since each organization is made up of multiple outputs, an overall evaluation must be able to compare the results of producing all outputs simultaneously. Regression analysis is incapable of doing this easily.

Another disadvantage is that regression analysis is an averaging relationship, taking into effect the efficient, as well as the inefficient, organizations. Therefore, it shows the average productivity of all organizations involved rather than the maximum efficiencies that the organizations are capable of attaining. The resulting regression line does not necessarily separate the inefficient units from the efficient units. It is possible for inefficient units to lie above the regression line and efficient units to lie below the regression line. For example, the lines connecting points A, B, C, and D in Figure 1 form a production frontier. There is no organization which produces a greater output level for the given input. Yet point A is below the regression line while points B, C, and D are above it even though all are on the

production frontier. In addition, point F, an inefficient point, is above the regression line.

One of the assumptions in using regression analysis is that the deviations from the regression line are random. This does not necessarily occur but can be caused by management techniques or technological differences. Regression is generally used more for predicting an estimated outcome given some historical data instead of being used in measuring productivity (13).

Data Envelopment Analysis. A third approach, DEA, is a relatively new method for measuring productivity. This model, developed by Charnes, Cooper and Rhodes (11), measures the relative productivity within not-for-profit organizations where the outputs have no "market value." This model is designed to handle multiple inputs and outputs simultaneously and develops an "efficiency frontier" (see Figure 1) made up of those organizations that are efficient relative to the other organizations under consideration. The "frontier" represents the maximum output for a given input. Each organization is referred to as a decision-making unit (DMU) and is assigned an efficiency rating relative to other DMUs on the frontier. A DMU which lies on the "efficiency frontier" is considered to be 100 percent efficient relative to the other units in the analysis set and is assigned a rating of 1.0.

Returning to Figure 1, points A, B, C, and D make up the efficiency frontier and therefore are rated 1.0. All other points are considered to be inefficient because they do not lie on the frontier, and therefore are assigned some positive rating less than 1.0. Simultaneously, the model identifies the amounts of inefficiency in each input and output for each DMU, permitting the calculation of efficient input and output levels.

DEA is an excellent starting point for making productivity enhancements in that it reveals which organizations in a group are inefficient and the sources and amounts of the inefficiencies. Further analysis can then determine the underlying causes that are making some DMUs inefficient relative to others. With this knowledge, decision makers can take action to adjust the input overages and output shortages to raise overall productivity.

In summary, ratio analysis is advantageous in that it is easy to understand and is most familiar to managers. Its major disadvantage lies in its inability to properly measure multiple inputs and outputs without subjectively assigning weights.

Regression analysis allows multiple inputs to be evaluated simultaneously, but is restricted to only one output at a time. In addition, regression analysis is an averaging process that considers both efficient and inefficient units in determining a "best fit." Finally,

it requires a priori judgment in the selection of a functional form.

DEA rank orders DMUs by degrees of efficiency relative to each other and is able to consider multiple inputs and multiple outputs simultaneously. Furthermore, it pinpoints the input overages and output shortages of the inefficient units needed by managers of these units in enhancing productivity levels.

Finally, a study done by Bowlin, Charnes, Cooper, and Sherman (7) compared the ability of ratio, regression, and data envelopment analysis to measure efficiency. They used a hypothetical data base consisting of 15 DMUs with known efficiencies and inefficiencies and applied each of the techniques to the data. The results showed data envelopment analysis to be superior to the other two techniques in identifying the sources and amounts of inefficiencies in the data.

Summary

This chapter contained a literature review on productivity and its measurement. The first section presented various ways productivity is defined and measured. The second section gave a general perspective of how productivity has declined over the past two decades. The third section discussed the Department of Defense's interest in productivity. Finally, three methods of measuring

productivity were presented. The formal DEA model was not included in the final section, but will be part of the next chapter, the methodology chapter.

III. Methodology

This chapter explains the methodology of this research. The first two research objectives, introduced in Chapter I, guide this research approach. These two objectives are:

1. Define the criteria for selecting the inputs and outputs for the DEA model.

2. Use this criteria to select the appropriate inputs and outputs that will best measure productivity within the TAC Accounting and Finance Offices.

This chapter is divided into three sections. The first two sections address objectives one and two. The third section presents and describes the DEA model along with the two approaches used in this research (i.e., window analyses and program versus managerial efficiency analysis).

Defining the Criteria for Selecting the Inputs and Outputs for the DEA Model

In selecting the inputs and outputs for the DEA model, it is essential that they properly represent the organizations. If a key input or output is left out, the results of the model may misrepresent the actual relative efficiency of the DMUs. In order to assure each organization is properly represented, the organization's management

should be involved in the selection of the inputs and outputs and the analyst should have a good understanding of how the organization works (13).

It is also important for the inputs and outputs to be controllable (i.e. adjustable) by management. This is important because the DEA model results show, in addition to the relative efficiency of each DMU, the input overages and output shortages of the inefficient units. If the inputs and outputs are not controllable by management, the results have limited usefulness in enhancing the efficiency of the DMUs rated inefficient.

Finally, all input and output values should have a value greater than zero and inputs and outputs should be related in such a way that an increase in an input should result in an increase in an output.

The TAC Accounting and Finance Office Organization. Each of the 18 accounting and finance offices (AFOs) within the Tactical Air Command are similar to all other AFOs throughout the USAF. Figure 2 shows the basic configuration of an accounting and finance office. The overall responsibility for each office rests on the shoulders of the Accounting and Finance Officer. The seven sections under the direction of the Accounting and Finance Officer are commonly referred to as subject matter areas (SMAs). The Military Pay, Travel, and Civilian Pay SMAs are responsible for maintaining and updating the pay, travel

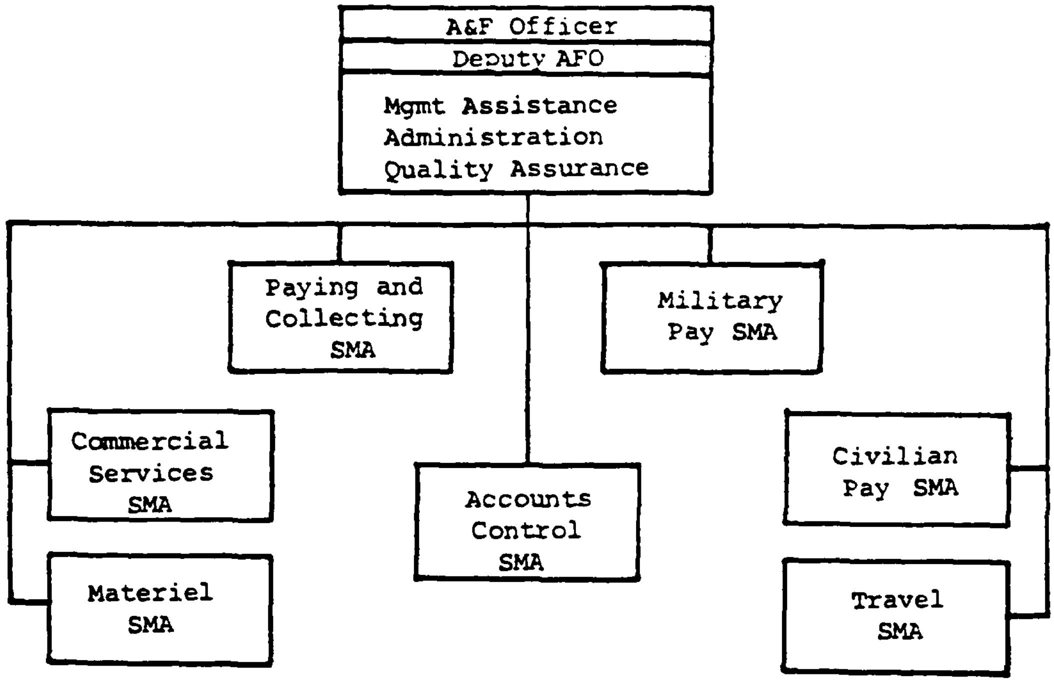


Fig. 2. Accounting and Finance Organization

and leave entitlements for all military personnel and DOD civilian employees assigned to the base, preparing the payroll for these personnel, and making intermediate payments to visiting personnel performing temporary duty at that installation. Additionally, each of these SMAs record all the financial transactions they make during a business day.

The Commercial Services and Materiel SMAs are responsible for paying for all the materials and services provided to the base. This entails making the initial certification of funds for contracts, obligating funds for approved contracts, and making payments to vendors as the base receives the requested supplies and services. This

requires entering accounting entries into a computer terminal as government funds flow through the various accounting stages.

While the previously mentioned five SMAs are responsible for preparing and certifying a wide range of payment and collection vouchers, none of these SMAs actually disburses any cash or checks. This function is accomplished by the Paying and Collecting SMA. The Chief of the Paying and Collecting SMA is an appointed agent of the United States Treasury (along with the Accounting and Finance Officer) and carries the title of Deputy Accounting and Finance Officer. A daily manual accountability of all cash, checks and U.S. savings bonds disbursed and collected is prepared by this SMA for each business workday.

The Accounts Control SMA, strategically located in the center of Figure 2, is often referred to as the hub of the office because they reconcile and control all the daily transactions processed by all the other SMAs. All accounting transactions flow into this SMA via the Merged Accountability and Fund Reporting (MAFR) System. This system consolidates the myriad of accounting transactions entered daily into the appropriate accounting classifications. At the end of each business workday, the Accounts Control SMA receives a MAFR report summarizing the accounting transactions for that particular day. This computer-generated report is then reconciled with the manual

accountability report submitted by the Paying and Collecting SMA. Any discrepancies between the two reports must be resolved that day. This SMA also loads all fund targets, released by the Budget Branch, into the accounting system, monitors the daily status of government funds, and prepares the majority of the accounting reports that are sent to higher headquarters.

To assist the Accounting and Finance Officer in the management of the office there is normally one deputy, a noncommissioned officer-in-charge (NCOIC), the Quality Assurance Section, and the Administrative Section. The Quality Assurance Section, headed by the Quality Assurance Manager, is the internal auditing function within the office. This section performs semi-annual audits of each SMA, reviews selected outgoing reports, collects and accumulates the results of customer surveys, and performs other various projects designed toward improving the overall quality of the office.

The above description of the accounting and finance office establishes the criteria from which the inputs and outputs for the DEA model should be formulated. It is important that the inputs and outputs properly capture the activities of the AFO as described above. This establishment of the input and output criteria fulfills the first research objective.

Selecting Input and Output Measures

Using the criteria outlined in the previous section, the author, with personnel from the Air Force Comptroller Management Engineering Team (AFCOMPMET) (14), selected the inputs and outputs for the DEA model as listed in Table 1. AFCOMPMET is the branch of AFMEA responsible for determining the standards for which all manning authorizations for the comptroller organizations are established. These inputs and outputs are taken from the work load factors established by AFCOMPMET for determining manning authorizations for the AFOs and are also used by AFMEA in the data submission for the annual productivity report presented to Congress and the President annually (33).

Inputs

Inputs. As mentioned in Chapter II, labor productivity is the measure that is used in this research. Labor productivity is calculated by dividing the total amount of output produced by the total amount of labor hours used in producing the output (24:2). Since the DEA model is able to handle multiple inputs and multiple outputs simultaneously, total labor in this case is measured by net man-hours used plus total annual employee compensation.

Net Man-hours Used. Net man-hours used are taken directly from the RCS: HAF-ACF(M) 7104, Report of Accounting and Finance Activities (referred hereafter as the 7104 Report). These hours represent the actual

TABLE 1

SUMMARY OF INPUT AND OUTPUT MEASURES

Measures	Description
<u>Input</u>	
Net Manhours Used	Represents the amount of time the work force is available for accomplishing accounting and finance work
Total Annual Employee Compensation	Surrogate measure for the number and skill level of personnel available for accounting and finance work
<u>Output Measures</u>	
Transactions Audited	Measures activity of the Accounts Control SMA
Military Personnel Serviced for Pay and Leave	Total number of military personnel serviced for pay and leave by the Military Pay SMA
Civilian Pay and Leave Accounts Maintained	Total active civilian pay and leave accounts maintained by the Civilian Pay SMA
Travel Transactions Processed	Total number of travel transactions processed during the month by the Travel SMA
Commercial Services Transactions Processed	Total number of commercial services transactions processed during the month by the Commercial Services SMA
Local Purchase Line Item Payment Transactions Processed	Total number of detail line item payments and deletion transactions completed by the Materiel SMA
Total Disbursement and Collection Vouchers Processed	Total number of disbursement and collection vouchers processed during the month by the Paying & Collecting SMA

time spent by military personnel and civilian employees in performing the accounting and finance work in each AFO.

Total Annual Employee Compensation. Total annual employee compensation is used as a surrogate input for skill level and experience. The assumption is made that higher wages paid to individuals are directly related to higher skills that come with experience and education. For example, the skills of an airman first class with two years military service is considered to be less developed than those of a staff sergeant with eight years military service and, therefore, the pay received by these two individuals is commensurable with this difference. This assumption applies to civilian employees as well.

Total annual employee compensation is computed by taking the total number of personnel in each grade structure assigned at the end of each month and multiplying them by their respective monthly composite pay rates. The number of personnel assigned was extracted from the 7104 Reports and the compensation figures were taken from Tables 3-3 and 3-8 in AF Regulation 173-13, U.S. Air Force Cost and Planning Factors (20:37,42).

The composite pay rates as of 1 October 1983 were used to compute the compensation totals for each of the time periods or DMUs (=twelve quarters and three years) that were used in this research. This was done in lieu of computing the totals using different annual pay charts and

subsequently adjusting these amounts to account for inflation. It is important that any such inputs or outputs measured in monetary terms are expressed in equivalent dollars. Otherwise, the latter year input/outputs would receive a higher weight (value) due to cost-of-living pay raises for these employees that would not reflect increased skill level and experience.

Because the computer software is unable to accept inputs or outputs greater than 999,999, the compensation figures are rounded to the nearest tenth, thereby allowing the last digit to be dropped. This has no effect on the analysis since DEA is unaffected by magnitude changes in a variable as long as the same change is made for all DMUs (5).

Outputs. The seven outputs in each of the two DEA models are the seven work load factors taken from the 7104 Report. Many of the work load factors are taken from the Selective Transaction History Listing, PCN SH069-931, a computer-generated report that lists the number of accounting transactions entered into the computer (17:86).

No output measure was selected to represent the work performed by the Accounting and Finance Officer and the management support personnel, because their duties are associated with the overall operation of the office and therefore have an impact on the performance of all the SMAs. Hours worked by these individuals are considered to

be "overhead costs," a term commonly used in the private sector to represent the costs which are incurred for the benefit of more than one internal unit in the organization and therefore are allocated to affected units based on some established scheme.

Transactions Audited. This variable measures the activity within the Accounts Control SMA. It is the total number of computer transactions processed by the AFO. The Accounts Control SMA is responsible for setting up and maintaining all the accounts that summarize these transactions and reconciling all the related financial records (17:34).

Military Personnel Serviced for Pay and Leave. This variable measures the activity within the Military Pay SMA. It is the total number of actual military personnel assigned as of the last day of the month (17:86).

Civilian Pay and Leave Accounts Maintained. This variable measures the work load within the Civilian Pay SMA. It represents the total number of civilian pay and leave accounts maintained for the last pay period of the month, plus the total gains and losses between this pay period and the last day of the month (17:87).

Travel Transactions Processed. This variable measures the activity within the Travel SMA. It includes the total transactions processed through the

computer by the Travel SMA personnel. A transaction is required for each accounting phase involving a travel payment which includes the commitment, obligation, advance payment and final payment of per diem and transportation funds (17:35,36,87).

Commercial Services Transactions Processed. This variable measures the work load of the Commercial Services SMA. It includes the total number of transactions entered into the computer to account for the commitment, obligation and payment of government funds for commercial services provided to the base. Transactions involving accounts receivables along with the storage and transportation of household goods are also included (17:36,87).

Local Purchase Line Item Payment Transactions Processed. This variable measures the work load of the Materiel SMA. It includes all computer transactions processed that are related to the acquisition and disposition of investment and expense materiels. The majority of the items are purchased through the six divisions of the Air Force Stock Fund Accounting and Reporting System (17:37,88).

Total Disbursement and Collection Vouchers Processed. This variable measures the activity of the Paying and Collecting SMA. It is the total number of

disbursement and collection vouchers processed by this SMA during the month (17:89,90).

Data Collection of Inputs and Outputs. The aforementioned inputs and outputs are extracted from the 7104 Report (1:1). Each AFO is required to submit this monthly report to their major command headquarters. At the headquarters, the data are summarized for the command and forwarded to AFAFC who, in turn, summarizes the data for all the AFOs in the USAF. The report includes a record of all hours worked in each SMA, subdivided into gross hours available, overtime hours, unavailable hours, loaned hours, borrowed hours, and net man-hours worked. The report also includes the work load factor for each SMA and a breakout of personnel assigned according to their Air Force Specialty Code (AFSC) by skill level and by SMA.

In an attempt to measure productivity over time using the DEA model, a minimum of three years data was deemed necessary. Only TAC Headquarters possessed the 1983 work load data necessary to fulfill this three-year data requirement. The 18 AFOs within this command were considered to be a sufficient number to make up a good representation of accounting and finance operations for this research. The 1984 and 1985 data were acquired from the AFAFC Directorate of Operations.

Data Envelopment Analysis (DEA)

DEA was developed by Charnes, Cooper and Rhodes (11) from a concept of efficiency proposed by Farrell in 1957 (22). They designed this nonlinear (nonconvex) programming model in order to establish a method for evaluating the activities of similar not-for-profit entities. Unlike profit-oriented organizations, no market exists for the outputs of nonprofit or government organizations such as the Air Force. Lacking a common standard, such as profit, it is very difficult to measure the efficiency of nonprofit entities. DEA allows similar nonprofit entitites to be measured relative to each other. Thus, DEA produces a measure of relative efficiency.

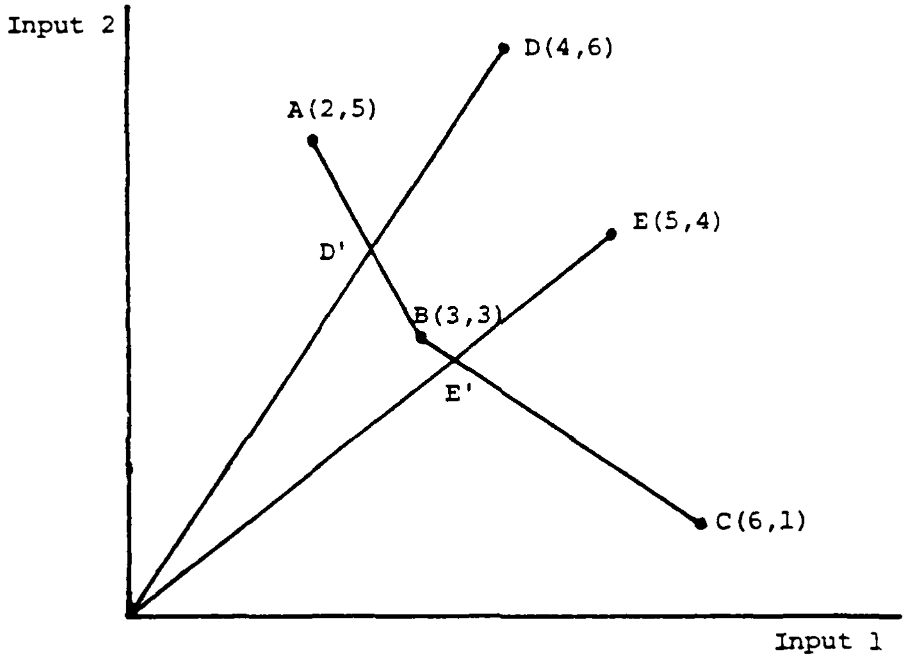
Each entity is referred to as a decision-making unit (DMU) and must be similar in that each DMU uses common inputs to produce common outputs. DEA uses linear fractional programming to simultaneously evaluate multiple inputs and multiple outputs from a set of DMUs. A DMU that produces the maximum outputs from the inputs it uses in comparison to the other DMUs under evaluation is considered to be 100 percent efficient and is assigned a rating of 1.0. These efficient units make up an efficiency frontier. Units not on the frontier are not necessarily as efficient as they possibly could be, but they are more efficient than the other DMUs in the comparison set.

Therefore, it is possible that the efficiency frontier could be expanded or shifted.

An example using a simple two input and one output model can better illustrate how DEA works. Figure 3 represents such an example comparing five organizations (DMUs), each producing one unit of output using various amounts of input 1 and input 2. This example was standardized with one unit of output so the graph could be limited to a two-dimensional Cartesian graph with input 1 plotted on the horizontal axis and input 2 plotted on the vertical axis.

The more efficient units appear closer to the origin because they are able to produce the same one unit of output as the others but with less inputs. For instance, DMU A is clearly more efficient than DMU D because it uses two units less of input 1 and one unit less of input 2 to produce the same one unit of output. Likewise, DMU B is clearly more efficient than DMU D and DMU E. But in comparing DMU A and DMU B, it is not clear which is more efficient. While DMU A uses one less unit of input 1 than DMU B, it uses two more units of input 2 that DMU B. The only way to determine which DMU is more efficient is to assign weights to each input.

But, as previously mentioned, inputs and outputs of non-for-profit entities may be noncommensurable and subjective weights difficult to defend. Therefore, the DEA



DMU	Input 1	Input 2	Efficiency
A	2	5	1.00
B	3	3	1.00
C	6	1	1.00
D	4	6	0.67
E	5	4	0.59

Fig. 3. How DEA Works

model establishes an "efficiency frontier" of the DMUs closest to the origin and the DMUs off the frontier and "enveloped" by this frontier are less efficient than those lying on the frontier. In Figure 3, DMUs A, B, and C make up the efficiency frontier and DMUs D and E are enveloped by this frontier.

Graphically, the efficiency rating is determined by drawing a line from the origin to the point representing the DMU and then dividing the distance from the origin to the point where the line crosses the efficiency frontier by the total distance to the point. In this example DMU D's and DMU E's efficiencies are calculated as follows:

$$OD'/OD = 0.59 \qquad OE'/OE = 0.67$$

This example demonstrates, in a simplified two input, one output model, how DEA works. Most models involve multiple inputs and multiple outputs, precluding them from being drawn graphically and require the use of a computer to be solved.

The graphical illustration just presented evolves from the DEA mathematical formulation introduced by Charnes, Cooper and Rhodes (11) which is a ratio of multiple outputs to multiple inputs as shown below.

$$\text{Maximize:} \qquad h_o = \frac{\sum_{r=1}^{s} U_r Y_{ro}}{\sum_{i=1}^{m} V_i X_{io}} \qquad (1)$$

Subject to:

$$1 \geq \frac{\sum_{r=1}^{s} U_r Y_{rj}}{\sum_{i=1}^{m} V_i X_{ij}}$$

$$j = 1, \ldots, n$$

$$U_r, V_i \geq \varepsilon \geq 0$$

where

h_o = the efficiency measure for DMU "0" which is the DMU being measured relative to the other DMUs.

X_{io} = the observed amount of the ith input used by DMU "0" during the observed period.

Y_{ro} = the observed amount of output "r" that DMU "0" produces during the observed period.

X_{ij} = the observed amount of the ith input that DMU "j" produces during the observed period.

Y_{rj} = the observed amount of output "r" that DMU "j" produces during the observed period.

V_i and U_r = values the model determines directly from the data to be used in the function.

ε = a small, positive non-Archimedian constant (6:73-74).

Charnes, Cooper, and Rhodes transformed this fractional programming problem into an equivalent linear programming problem using the theory of linear fractional

programming. A detailed explanation of this mathematical transformation is not shown here but can be found in (11). The linear programming equation is presented below.

$$\text{Minimize:} \qquad h_o = \theta - \varepsilon \left(\sum_{r=1}^{s} S_r^{+} + \sum_{i=1}^{m} S_i^{-} \right) \qquad (2)$$

$$\text{Subject to:} \qquad \sum_{j=1}^{n} Y_{rj} \lambda_j - S_r^{+} = Y_{ro}$$

$$r = 1, \ldots, s;$$

$$- \sum_{j=1}^{n} X_{ij} \lambda_j - S_i^{-} + \theta X_{io} = 0$$

$$i = 1, \ldots, m$$

$$\lambda_j, S_r^{+}, S_i^{-} \geq 0$$

θ unrestricted in sign

where

θ = the intensity multiplier of input X_{io},

λ = variable determined by the model,

S_r^{+} = output slack value for output "r",

S_i^{-} = input slack value for input "i",

ε = a small, positive non-Archimedian constant (6:80).

By solving equation (2), the amount of inefficiency present in the inputs and outputs can be obtained. Then following the method designed by Charnes, Cooper, and Rhodes (11), the inputs and outputs of the DMUs found to be inefficient can be adjusted to make them efficient. The adjustments are as follows:

$$\hat{X}_{io} = X_{io} - S_i^{-*} \tag{3}$$

$$\hat{Y}_{ro} = \frac{1}{\theta^*} Y_{ro} + S_r^{+*} \tag{4}$$

where * indicates an optimum value from the solution of (2) and:

$\hat{X}_{io}$ = value of adjusted efficient input "i" for the organization being evaluated

$\hat{Y}_{ro}$ = value of adjusted efficient output "r" for the organization being evaluated

<u>Window-type Analyses</u>. In applying window-type analyses to the 18 accounting and finance offices, the data is totaled by calendar year (CY) quarter (three-month periods). Then a series of 10 analyses are run for each base, each including three quarters of data. The first analysis consists of DMUs representing quarterly operations for quarters 1, 2, and 3 of CY83 for all 18 AFOs. For the second analysis, the first quarter is dropped and the fourth quarter added, resulting in an analysis for

quarters 2, 3, and 4 of CY83 for all 18 AFOs. Quarters 2 and 3 are represented twice in this series of analyses. This dropping and adding of one quarter's data is continued until all 12 quarters are included. There are 54 DMUs in each analysis (three quarters of data time 18 bases).

Table 2 illustrates how the quarterly data are combined. Quarters 3 through 10 each appear in three separate analyses, because of the "moving window" provided by dropping one quarter and adding another each time. Each quarter is observed to see if there is a change in efficiency as it is first analyzed with older data and then with more recent data. If the AFOs are increasing productivity over time, the DMUs for any one quarter should become less efficient with subsequent analyses because they are compared with more productive DMUs of future periods.

An example can help explain how this works. Taking quarter 6 as an hypothetical example, it can be seen that this quarter will have three efficiency ratings from three subsequent analyses (analyses 4, 5, and 6) for each DMU. In analysis 4, quarter 6 is compared with quarters 4 and 5. If this AFO has become more productive with the passing of each quarter, then quarter 6 should have a higher efficiency rating than quarters 4 and 5. In analysis 5, quarter 6 is compared with quarters 5 and 7. This time,

TABLE 2

WINDOW-TYPE ANALYSES USING THREE QUARTERS

Analysis Number	Quarter Number 1	2	3	4	5	6	7	8	9	10	11	12
1	X	X	X									
2		X	X	X								
3			X	X	X							
4				X	X	X						
5					X	X	X					
6						X	X	X				
7							X	X	X			
8								X	X	X		
9									X	X	X	
10										X	X	X

quarter 7 should have the highest efficiency rating over quarters 5 and 6. Likewise, in analysis 6, quarter 8 should be the most efficient, quarter 7 less efficient and quarter 6 the least efficient. Consequently, quarter 6 should become less efficient as it is compared to more recent quarters if productivity or efficiency improvements are occurring. Figure 4 shows how this one quarter's data (i.e., quarter 6) becomes less efficient with subsequent analyses, using hypothetical efficiency ratings.

Program versus Managerial Efficiency. As stated in Chapter I, this approach was first used by Charnes, Cooper, and Rhodes (CCR) in their work with Program Follow Through (10). This method also is used in this thesis

Analysis	Quarter 4	5	6	7	8
4	0.975	0.987	1.000		
5		0.975	0.987	1.000	
6			0.975	0.987	1.000

Fig. 4. Example of Window-type Analyses

to detect changes in productivity within the TAC AFOs between CY83 and CY85.

This process requires running a series of four data envelopment analyses. First, a data envelopment analysis is accomplished for CY83 annual data for all 18 AFOs using model (2). The results of this analysis are "adjusted" to make all 18 of these DMUs 100 percent efficient using equations (3) and (4). These adjustments represent the managerial inefficiencies that have precluded some AFOs from obtaining a 100 percent efficiency level relative to the other AFOs within TAC for that particular year.

The second and third analyses involve a similar process using CY84 and CY85 data. Once all three analyses are accomplished and appropriate adjustments made, a final analysis using all 54 efficient DMUs is run. Since each year's data is already adjusted to account for managerial inefficiencies, the resulting changes in efficiency levels should be a result of program changes or, in other words,

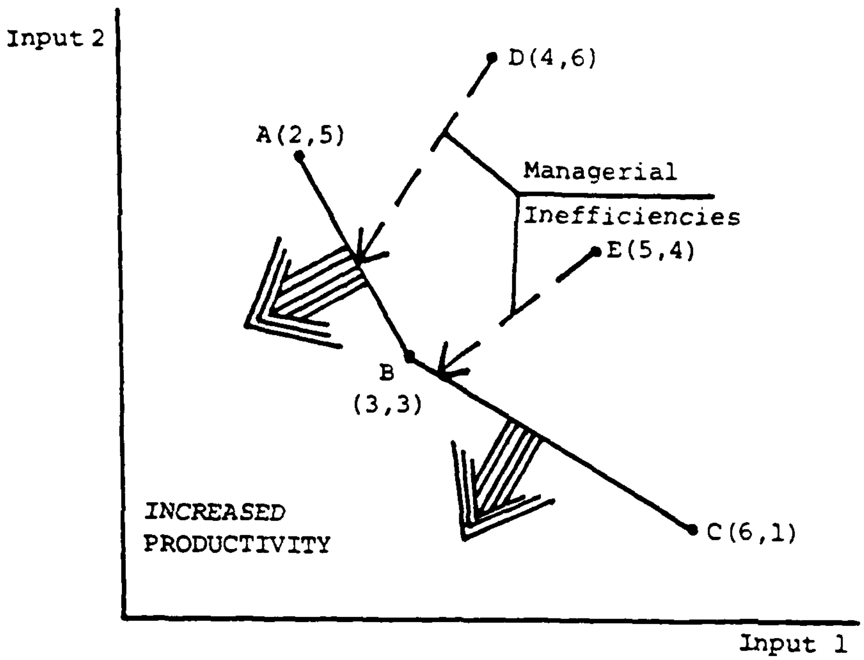


Fig. 5. Eliminating Managerial Inefficiencies and Shift in the Efficiency Frontier

command-wide changes in operations between the years. If productivity has increased for these 18 AFOs over time the efficiency levels for 1985 DMUs should be higher than 1984 DMUs and 1983 DMUs.

Figure 5 graphically demonstrates how this process is accomplished using the simplified example from Figure 3. Points A through E represent one program or year. By adjusting D and E to bring them on to the efficiency frontier, "managerial efficiencies" will be eliminated for that year. Adding subsequent programs represented by more recent yearly efficient data to the comparison set should result in this "efficiency frontier" shifting to the left as productivity increases.

Summary

This chapter discussed the methodology that is used for this thesis. The first two sections answered research objectives one and two.

1. Define the criteria for selecting the inputs and outputs for the DEA model.

2. Use this criteria to select the appropriate inputs and outputs that will best measure productivity within the TAC Accounting and Finance Offices.

The third section presented the formal DEA model. The author used a simple one input, one output model to illustrate how DEA works. Finally, the two DEA approaches, window analyses and program versus managerial efficiency, used in this research were described.

IV. Analysis and Results

This chapter explains the analysis and results of this research. Research objectives three and four, introduced in Chapter I, guide this analysis. These two objectives are:

3. Develop DEA models for measuring the productivity of the TAC Accounting and Finance Offices.

4. Use the results of the models to test for productivity changes over time.

This chapter contains four sections. The first section discusses the computer resources used in this analysis. The second section displays the results and analysis of the DEA model using the window analyses approach. The third section displays the results and analysis of the DEA model using the program versus managerial efficiency approach. The fourth section summarizes the results of these analyses.

Computer Resources

The Productivity Assessment Support System (PASS) software package developed by Bessent, Bessent and Elam-Vidmar (4) is used to perform these analyses. This software package is used on an IBM-AT personal computer equipped with a primary memory, 20-megabyte hard disk

running under DOS 3.0. The IBM-AT also is equipped with a color graphics monitor and printer required by PASS (4:4). PASS is written in dBase III with an embedded optimizer (4:4).

PASS is designed to perform Constrained Facet Analysis (CFA) as designed by A. Bessent and others (3). CFA is a technique which works on the principle of extending the efficiency frontier developed by DEA in an attempt to "envelop" observations that fail to be enveloped by DEA (13). In doing so, it is necessary to solve the DEA model. These DEA results are extracted for this research.

Window Analyses Results

This approach involved executing the DEA model 10 times with 54 DMUs in each analysis. As outlined in Chapter III, the first analysis includes quarters 1, 2, and 3 of CY83 for the 18 AFOs. In the second analysis, the first quarter is dropped and the fourth quarter for CY83 added for each of the AFOs. Each subsequent analysis involves dropping the oldest quarter's data from the previous analysis and adding the next quarter's data until all 12 quarters for CY83 through CY85 for each AFO are included in an analysis.

The results of the analyses for Base 2 are shown in Table 3 and a complete set of results for all 18 bases is shown in the appendix. The focus of these tables is on changes among the efficiency levels for individual quarterly

TABLE 3

WINDOW ANALYSES RESULTS FOR BASE 2

Base 2												
Anal-ysis	Quarter											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.828	0.866	0.850									
2		0.866	0.850	0.984								
3			0.867	0.984	0.860							
4				1.000	0.879	0.995						
5					0.786	0.901	1.000					
6						0.897	1.000	0.998				
7							1.000	0.998	0.904			
8								0.977	0.892	0.963		
9									0.862	0.911	0.887	
10										0.904	0.870	0.789

data over the series of analyses in which it is involved. For example, reviewing Table 3, we see that Base 2 received an efficiency rating of 0.850 for its third quarter of operations in analysis 1. Its rating did not change for analysis 2 when the first quarter's data was dropped and the fourth quarter data added. In analysis 3, when data for quarter 2 was dropped and data for quarter 5 added, Base 2's third quarter efficiency rating increased to 0.867.

As explained in Chapter III, one purpose of these analyses is to test for changes in productivity over a three consecutive quarter time frame. Increased productivity in this case is exemplified by a decrease in the efficiency rating for a quarter's data as subsequent analyses are performed. For example, quarter 6 in Table 3 decreased from an efficiency rating of 0.995 in analysis 4 to 0.901 in analysis 5 and to 0.897 in analysis 6. However, the results for these 10 analyses show only a minority of efficiency ratings actually decreasing as in this example.

A summary of the shifts in the efficiency ratings between analyses within individual quarters is shown in Table 4. This table includes quarters 2 through 11, the quarters involved in more than one analysis. A decrease in this table represents a decline in efficiency between two analyses without a subsequent increase between the

TABLE 4

SUMMARY OF SHIFTS IN EFFICIENCY RATINGS
FOR WINDOW-TYPE ANALYSES

Base	Decrease	No Change	Increase	Fluctuation
1	4	3	0	3
2	5	2	2	1
3	2	4	2	2
4	2	2	2	4
5	3	3	4	0
6	3	0	5	2
7	0	7	2	1
8	6	1	0	3
9	0	9	0	1
10	0	8	1	1
11	5	2	0	3
12	3	5	1	1
13	3	2	1	4
14	3	5	0	2
15	6	1	1	2
16	3	6	1	0
17	4	6	0	0
18	1	5	2	2
Total	53	71	24	32
% of Total	29.4	39.4	13.3	17.8

remaining two analyses. For example, in Table 3, quarters 6, 8, 9, 10, and 11 were recorded as decreases in efficiency. Notice quarter 8 is considered a decrease even though the efficiency rating remained constant between analyses 6 and 7. Likewise, an increase represents an increase in the efficiency rating between any two analyses without a subsequent decrease in the efficiency rating. Quarters 3 and 4 in Table 3 experienced increases. A quarter is put in the no change category when the efficiency rating remains constant for all analyses involving that quarter's data. This occurs in quarters 2 and 7 for Base 2. Finally, if the efficiency level increases and subsequently decreases or vice versa, then it is considered a fluctuation. This occurs in quarter 5 for Base 2.

Table 4 shows 29.4 percent of the efficiency ratings decreasing, 39.4 percent remaining constant, 17.8 percent fluctuating, and 13.3 percent increasing for the 18 bases. Thus, these results do not provide any significant indication of increases or decreases in productivity over the three-year period.

Note that window analyses is a smoothing technique analogous to smoothing techniques used in econometrics. By using this technique, we are able to "smooth out" the impact of changing reference sets over time and check for trends. Hence, by employing least-squares regression in conjunction with the window analyses we are able to

check for increases in efficiency over time for the Tactical Air Command's AFOs.

This is done via the following process. First, the average efficiency level for each quarter for all 18 bases is determined by adding all the efficiency ratings for each quarter and dividing them by the number of efficiency ratings for that quarter (18 for quarters 1 and 12, 36 for quarters 2 and 11, and 54 for quarters 3 through 10). These average efficiency ratings are then regressed over time. The resultant regression line equation is:

$$Y = 0.0010X + 0.9424$$

where Y = the average efficiency rating for the command, and

X = time (analysis quarter 1, 2, ..., 12).

The average efficiency ratings and regression line are plotted in Figure 6. The regression equation shows a positive slope coefficient of 0.0010; however, the accompanying t-test indicated only a 49.11 percent chance that this coefficient is actually greater than zero. In other words, there is a 51 percent chance that the slope of the regression line is zero which indicates that there is not a positive trend in the data. Based on these results, it cannot be concluded that productivity has actually increased over this three-year period.

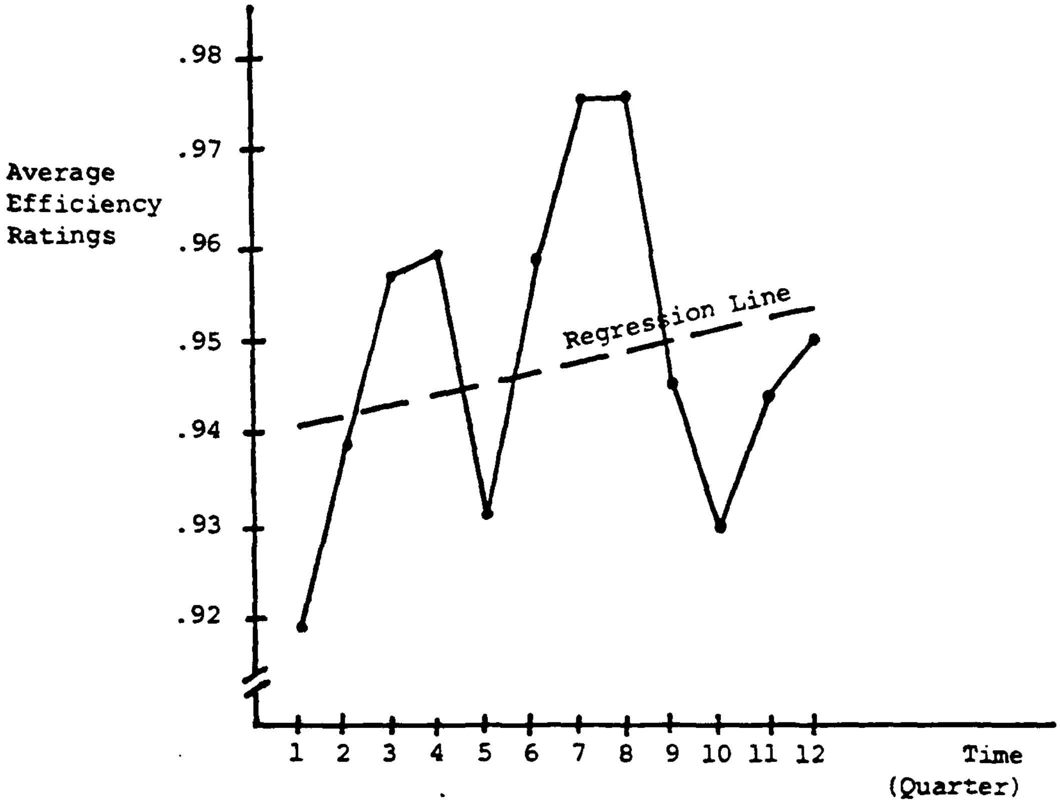


Fig. 6. Window Analyses Plotted Over Time

<u>Program versus Managerial Efficiency Results</u>

A possible problem with the previous window analyses approach is the confounding effect that managerial inefficiencies could have on the analysis by overshadowing increased efficiencies resulting from programmatic changes. Hence, another approach to pinpointing productivity over time is to control for the effect of managerial inefficiencies. In this approach, managerial inefficiencies are removed from each year's data, thereby making the inefficient DMUs efficient and shifting them on to the efficiency frontier.

As explained in Chapter I, this approach separates the inefficiencies into two separate types: program and managerial. The managerial inefficiencies are the output shortages and input overages of the inefficient DMUs for a specific year that precludes them from reaching the efficiency frontiers formulated by the efficient DMUs. By adjusting these DMUs and bringing them to the efficiency frontier, managerial inefficiencies are removed. The new efficiency frontier represents the program, in the true sense, for that year's data and can be compared with other programs in detecting productivity changes over time. This is a three-step process.

The first step of this process involves running the DEA model three times--once for each year's data for all 18 AFOs. The efficiency levels for these three analyses are shown in Table 5. While some DMUs are consistently rated efficient relative to other DMUs for a particular year, others remain consistently low and a few fluctuate between a high efficiency rating and a low efficiency rating and vice versa. Eleven DMUs are efficient in the first analysis (1983 data), while 12 and 10 DMUs are rated efficient in the second (1984 data) and third (1985 data) analysis, respectively. Nine DMUs (1, 5, 7, 9, 10, 14, 16, 17, and 18) are rated efficient in all three years. The least efficient DMU is a different DMU each year (DMU 8 for 1983, DMU 15 for 1984, and DMU 2 for 1985).

TABLE 5

DEA EFFICIENCY LEVELS FOR ANNUAL DATA

DMU	1983	1984	1985
1	1.000	1.000	1.000
2	0.929	1.000	0.904
3	1.000	1.000	0.982
4	0.968	0.968	0.939
5	1.000	1.000	1.000
6	0.919	0.961	0.975
7	1.000	1.000	1.000
8	0.897	0.914	0.923
9	1.000	1.000	1.000
10	1.000	1.000	1.000
11	1.000	0.946	0.999
12	0.979	1.000	1.000
13	0.977	0.960	0.990
14	1.000	1.000	1.000
15	0.899	0.841	0.919
16	1.000	1.000	1.000
17	1.000	1.000	1.000
18	1.000	1.000	1.000

DMU 2 is the most inconsistent DMU, jumping from an efficiency rating of 0.929 in 1983 to 1.0 in 1984 and to 0.904 in 1985, making it the least efficient DMU for 1985. However, a direct comparison across calendar years for each AFO is not meaningful since the reference sets are different for each year. That is, DMU 1's rating for 1983 cannot be meaningfully compared to its rating for 1984 and/or 1985 since the comparison bases or set for each year are different.

The second step in this analysis is to adjust the input and output values of the inefficient DMUs for each of these three analyses, using equations (3) and (4) in Chapter III, so that all DMUs are efficient and therefore lie on the efficiency frontier for that year of operation. The adjustments for DMU 2 for 1983 are shown as an example of this adjustment process in Figure 7. In this case the θ^* value is equal to 0.929. After the adjustments were made for all DMUs for all years, each analysis was reexecuted to assure all DMUs were efficient. The results gave all DMUs an efficiency rating of 1.0 as expected.

The final step involves running the DEA model with all 54 efficient DMUs together to test for productivity changes over time due to program efficiencies. Recall from Chapter III that since the managerial inefficiencies have been removed from the data by bringing each DMU to the efficiency frontier for each year of operations, any

Output Number	Original Output Level	x	$\frac{1}{\theta^*}$	+	Shortage (Slack)	=	Efficient Level
1	221,044		1.076				237,835
2	40,224		1.076		6,236		49,515
3	5,979		1.076		3,638		10,071
4	39,722		1.076		18,806		61,545
5	49,517		1.076				53,278
6	148,490		1.076		53,307		213,077
7	89,674		1.076				96,486

Input Number	Original Input Level	-	Excess	=	Efficient Level
1	77,977		1,212		76,765
2	78,303				78,303

Fig. 7. Adjusting DMUs to Efficiency

inefficiencies that become evident in this step could be assumed to result from program changes. The results of this analysis are shown in Table 6.

Between the first two years (1983 and 1984), nine DMUs show an increase in efficiency levels, while three DMUs show decreases and six DMUs remain constant. Between the second two years (1984 and 1985), five DMUs increase while five decrease and eight remain constant. All but one of the DMUs that remain constant over the three-year period did so because they are already rated 1.0 efficient.

For the three-year period (1983 through 1985), 13 DMUs increase, two decrease, and three remain the same, indicating a majority (72.2 percent) of the bases showing increases in productivity. The three DMUs with no change over this three-year period are all rated 1.0 efficient in 1983 and 1985.

Continuing the analysis, least-squares regression is again used to check for changes over time. The efficiency ratings of the 54 DMUs are regressed over time. The resultant regression equation and raw efficiency levels are plotted in Figure 8. The numbers in parentheses next to some of the points indicate the number of DMUs with that efficiency rating. The regression line equation is:

$$Y = 0.0102X + 0.9688$$

where Y = average efficiency rating, and

X = time (analysis year 1, 2, 3).

TABLE 6

DEA EFFICIENCY LEVELS AFTER ELIMINATING MANAGERIAL INEFFICIENCIES

DMU	1983	1984	1985
1	0.987	1.000	1.000
2	0.980	0.937	1.000
3	1.000	1.000	0.999
4	0.934	1.000	0.993
5	1.000	0.982	1.000
6	0.959	1.000	0.991
7	1.000	1.000	0.971
8	0.914	0.988	0.999
9	1.000	1.000	1.000
10	0.979	1.000	1.000
11	0.995	0.995	1.000
12	0.990	1.000	1.000
13	0.997	0.980	1.000
14	0.909	1.000	1.000
15	0.944	1.000	0.998
16	1.000	1.000	1.000
17	1.000	1.000	1.000
18	0.996	1.000	1.000

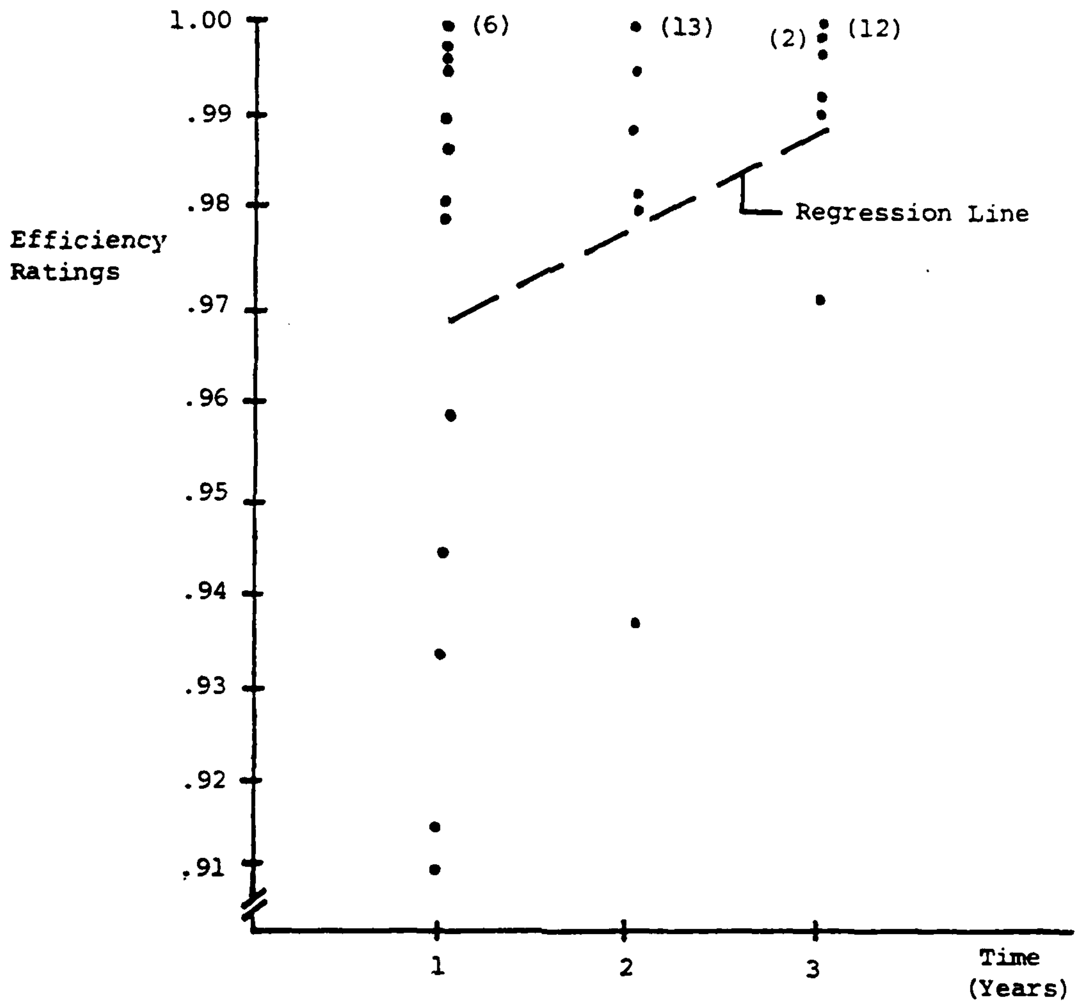


Fig. 8. Program Efficiency Plotted Over Time

The regression line shows a positive slope coefficient of 0.0102 indicating an overall increase in productivity. The t-test supports this increase in productivity by indicating a 99.6 percent chance that this coefficient is in fact positive.

However, discussions with Mr. Richard L. Murphy, Assistant Professor of Quantitative Price Analysis, at the Air Force Institute of Technology (28), indicated that by adjusting the inefficient units and shifting them on to the efficiency frontier, the efficiency frontier may have become distorted, creating biased results. Murphy suggested an additional analysis be executed using only the efficient DMUs making up the original efficiency frontiers for each individual year's data. This analysis includes the 33 efficient DMUs as shown in Table 5. The results of this analysis are displayed in Table 7. A comparison of these DMU values with the values from Table 6, which includes results for all 54 DMUs, shows these DMUs have identical efficiency ratings. This indicates that the adjusted DMUs did not become reference points for any inefficient DMU when executed in the 54 DMU DEA model which provides an indication that these units are outliers. In other words, the adjustment process does not affect the efficiency ratings of the 54 DMUs when executed in the DEA model.

TABLE 7

DEA EFFICIENCY LEVELS RESULTING FROM AGGREGATING EFFICIENT DMUS FROM INDIVIDUAL ANNUAL DATA

DMU	1983	1984	1985
1	0.987	1.000	1.000
2	*	0.937	*
3	1.000	1.000	*
4	*	*	*
5	1.000	0.982	1.000
6	*	*	*
7	1.000	1.000	0.971
8	*	*	*
9	1.000	1.000	1.000
10	0.979	1.000	1.000
11	0.995	*	*
12	*	1.000	1.000
13	*	*	*
14	0.909	1.000	1.000
15	*	*	*
16	1.000	1.000	1.000
17	1.000	1.000	1.000
18	0.996	1.000	1.000

*DUM rated inefficient in original DEA.

Since the DMUs in this analysis are not the same for each year, no comparison can be made by each individual base over time. Therefore, the DEA efficiency levels are regressed over time. The resultant regression equation and raw efficiency levels are plotted against time in Figure 9. The regression equation is:

$$Y = .0047 + .9834$$

where Y = efficiency rating, and

X = time (years 1, 2, 3).

The slope coefficient of this line is 0.0047, a significant decrease from the 0.0102 in the analysis involving all 54 DMUs. The t-test for this equation also decreases significantly, showing only a 71.68 percent chance that the slope coefficient is positive, a decrease from 99.6 percent in the previous analysis. It appears that the inclusion of the 21 adjusted DMUs in the original analysis involving the 54 DMUs bias the regression results. These results indicate there is a 28.32 percent chance that the slope coefficient is actually zero and no trend exists in the data. Therefore, it cannot be concluded from this analysis that productivity for these 18 AFOs actually increased during this three-year period.

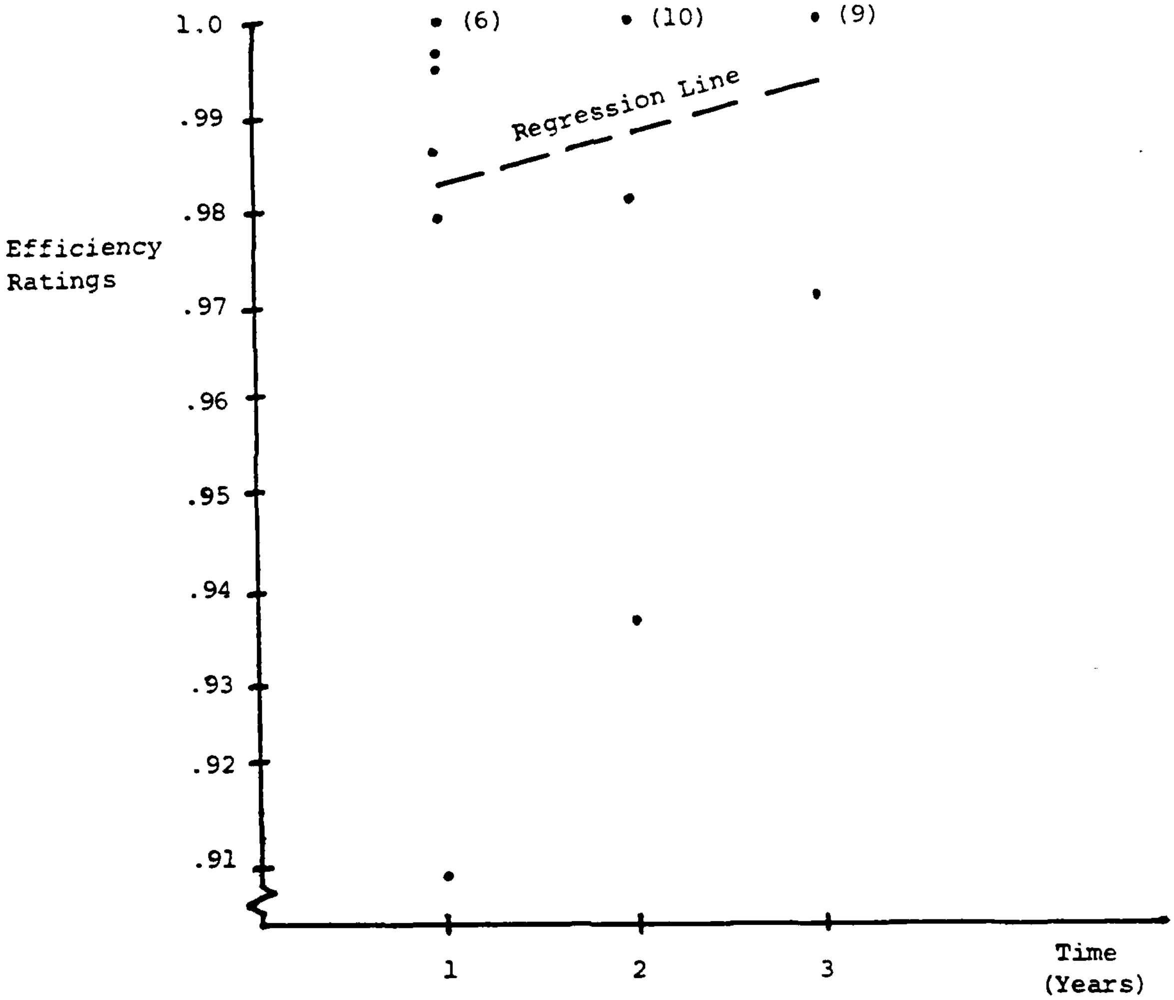


Fig. 9. Efficient DMUs from Separate Annual Analyses Plotted Over Time

Summary

This chapter discussed the results and analysis of this research. Research objectives three and four were addressed.

3. Develop DEA models for measuring the productivity of the TAC Accounting and Finance Offices.

4. Use the results of the models to test for productivity changes over time.

First the computer resources were discussed, followed by the two approaches using DEA to evaluate productivity over time: window analyses and program versus managerial efficiency.

The window analyses approach tested for productivity changes over time by focusing on one quarter of data at a time in comparison with older data and more recent data. Using this approach, an increase in productivity is reflected by a decrease in the efficiency rating for a quarter's data (DMU) as subsequent analyses are performed (compared with more recent data). The results showed less than 30 percent of the efficiency ratings decreasing within the 10 quarters observed for the 18 bases. Continuing the analysis, least-squares regression was performed on the average quarterly efficiency ratings for these DMUs over time. This also failed to indicate an increase in productivity because of wide fluctuations in the efficiency ratings.

The second approach, program versus managerial efficiency, indicated a more positive change in productivity. Regressing the efficiency ratings against time supported this change in productivity. However, a subsequent check for potential biases caused by the adjustment process for managerial inefficiencies, significantly reduced the reliability of these original results. An analysis comparing only the efficient DMUs from the efficiency frontiers of the separate annual programs reduced the significance level to an unacceptable level. These results indicated only a 28.32 percent chance that the slope coefficient was zero and no trend existed. Therefore, it could not be concluded productivity increased for the TAC AFOs between 1983 and 1985.

The next chapter presents conclusions to this research and makes recommendations for further research.

V. Conclusions and Recommendations

This chapter is divided into two sections. The first section will summarize the results of this research and make conclusions from these results. The second section fulfills the last research objective.

5. Make recommendations for further testing and using DEA to measure productivity for command and base level accounting and finance offices.

Conclusions

This thesis tests the feasibility of using DEA to measure productivity improvements within the Tactical Air Command Accounting and Finance Offices using the Data Envelopment Analysis model. Specifically two approaches, window analyses and program versus managerial efficiency, are used to test for productivity changes over a three-year (1983 through 1985) period.

Each approach indicates a potential positive trend in productivity, but the corresponding statistical tests fail to provide conclusive evidence to support an actual increase during this period. This means that either productivity did not increase over this period or that it did increase but was masked by significant fluctuations in the productivity rates (increases or decreases) among

the individual bases. Another possibility is that the increase was very slight, possibly due to phasing in productivity or efficiency enhancements, and could not be identified over the short time period of three years.

Recall from Chapter II that the Air Force accounting and finance network has initiated several productivity enhancements such as implementation of the JUMPS Data Collection System, Flat Rate Per Diem, and the PEERS program.

While many initiatives have enhanced productivity, other initiatives may have had the opposite effect. Changes in entitlements or the way they are computed, such as the new G.I. Bill, acceleration of debt collection and extension of the payback period for advance pay, have increased the work load of the AFOs. One program, the Automated Travel Record and Accounting System, created to improve the travel accounting system, has resulted in more, rather than less, work. This system has significantly complicated the processing of travel accounting transactions.

Overall, the productivity enhancements should have surpassed the negative impacts. Unfortunately, the statistical tests accompanying the DEA results failed to positively reveal any increases in productivity during this time.

Recommendations

Following are the recommendations by the author for further research into the feasibility of using DEA to measure productivity within command and base level AFOs.

1. The results using the program versus managerial efficiency approach showed signs of productivity increases using DEA efficiency levels plotted over time for both the 54 DMU and 33 DMU data sets. However, statistical tests for the 33 DMU model failed to support a conclusion of productivity improvement. This could have occurred because of the low productivity increases masked by fluctuations among individual bases. Further research might concentrate on using this one approach but over a longer period of time. By increasing the time frame over which data is collected and compared, productivity enhancements should become more visible and therefore increase chances of statistical significance.

2. Another avenue of possible research is to compare productivity increases in an absolute sense versus a relative sense. Figure 10 illustrates in a simplified manner how the piece-wise linear efficiency frontier establishes the reference set for inefficient units. In this example, points A and B are the reference set for point E. Likewise, points B and C determine the efficiency levels for F and G and, finally, C and D for point H. Further research might test the feasibility of determining

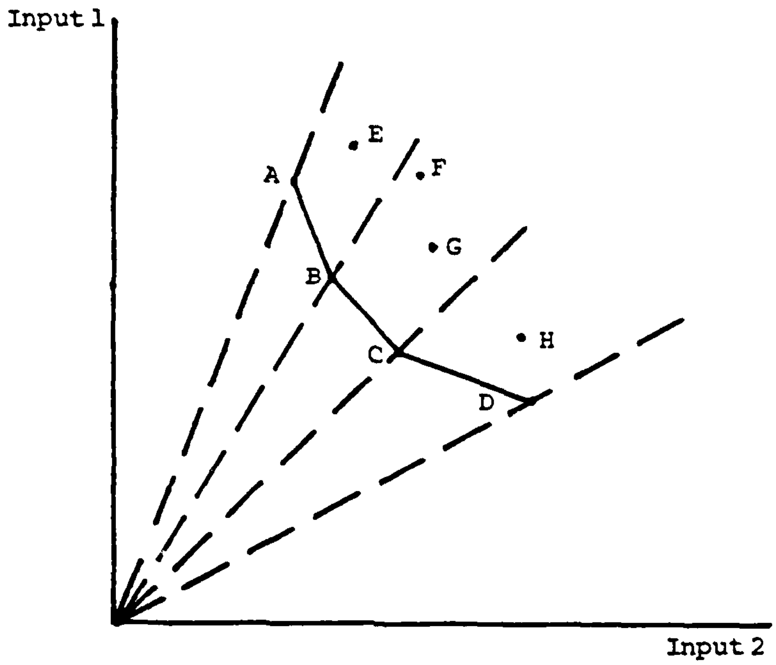


Fig. 10. Establishing Reference Sets for Inefficient DMUs

reference sets for DMUs rated inefficient one year and then by holding the reference set constant, measure subsequent absolute changes in efficiency levels for latter year DMUs within this reference set.

Appendix: Results of Window Analyses

Base 1

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.951	0.929	0.977									
2		0.911	0.971	1.000								
3			0.967	1.000	0.901							
4				1.000	0.925	1.000						
5					0.918	1.000	1.000					
6						0.982	1.000	1.000				
7							1.000	1.000	0.970			
8								1.000	0.962	0.920		
9									0.991	0.950	0.917	
10										0.927	0.915	1.000

Base 2

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.828	0.866	0.850									
2		0.866	0.850	0.984								
3			0.867	0.984	0.860							
4				1.000	0.879	0.995						
5					0.786	0.901	1.000					
6						0.897	1.000	0.998				
7							1.000	0.998	0.904			
8								0.977	0.892	0.963		
9									0.862	0.911	0.887	
10										0.904	0.870	0.789

Base 3

Anal-ysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	1.000	1.000	1.000									
2		1.000	1.000	0.987								
3			1.000	0.988	0.997							
4				1.000	0.996	1.000						
5					0.997	1.000	1.000					
6						0.967	1.000	1.000				
7							1.000	1.000	0.955			
8								1.000	0.937	0.928		
9									1.000	1.000	0.864	
10										1.000	0.842	0.996

Base 4

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.867	0.871	0.940									
2		0.871	0.940	0.940								
3			0.931	0.930	0.961							
4				0.959	0.990	0.958						
5					0.975	0.959	1.000					
6						0.935	1.000	0.931				
7							1.000	0.945	0.912			
8								0.956	0.917	0.920		
9									0.917	0.905	0.922	
10										0.906	0.913	0.980

Base 5

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.978	1.000	0.961									
2		1.000	0.961	0.940								
3			1.000	0.952	0.981							
4				0.995	1.000	1.000						
5					1.000	1.000	0.988					
6						1.000	1.000	0.989				
7							1.000	0.988	1.000			
8								0.962	0.971	0.959		
9									0.956	0.942	1.000	
10										0.940	1.000	0.920

Base 6

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.856	0.882	0.883									
2		0.868	0.871	0.919								
3			0.870	0.921	0.897							
4				0.923	0.883	0.987						
5					0.882	0.990	0.984					
6						0.962	0.975	0.943				
7							0.976	0.947	0.950			
8								0.961	0.971	0.940		
9									1.000	0.954	0.866	
10										0.955	0.867	0.949

Base 7

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.941	0.957	1.000									
2		0.957	1.000	1.000								
3			1.000	1.000	0.987							
4				1.000	0.986	1.000						
5					0.990	1.000	1.000					
6						1.000	1.000	1.000				
7							1.000	1.000	0.975			
8								1.000	0.978	0.978		
9									1.000	1.000	0.938	
10										1.000	0.938	0.934

Base 8

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.790	0.858	0.849									
2		0.858	0.849	0.843								
3			0.836	0.821	0.822							
4				0.845	0.820	0.890						
5					0.794	0.880	0.895					
6						0.879	0.888	1.000				
7							0.888	1.000	0.848			
8								0.999	0.818	0.995		
9									0.849	1.000	0.854	
10										0.963	0.832	0.853

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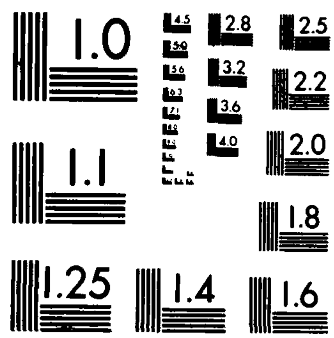

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Base 9

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.974	0.974	1.000									
2		0.974	1.000	1.000								
3			1.000	1.000	1.000							
4				1.000	1.000	1.000						
5					1.000	1.000	1.000					
6						1.000	1.000	1.000				
7							1.000	1.000	1.000			
8								1.000	0.966	1.000		
9									0.968	1.000	1.000	
10										1.000	1.000	1.000

Base 10

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.917	1.000	1.000									
2		1.000	1.000	1.000								
3			1.000	1.000	1.000							
4				1.000	1.000	1.000						
5					1.000	1.000	1.000					
6						1.000	1.000	0.985				
7							1.000	0.986	0.982			
8								1.000	0.974	1.000		
9									0.978	1.000	1.000	
10										1.000	1.000	0.986

Base 11

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.865	1.000	1.000									
2		1.000	1.000	0.924								
3			1.000	0.922	0.837							
4				0.922	0.853	0.849						
5					0.838	0.848	1.000					
6						0.798	0.984	0.959				
7							0.984	0.959	0.883			
8								0.947	0.872	0.942		
9									0.900	0.987	0.992	
10										0.966	0.967	0.952

Base 12

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.960	0.847	0.943									
2		0.847	0.943	0.960								
3			0.940	0.960	0.937							
4				0.969	0.939	1.000						
5					0.855	0.935	1.000					
6						0.935	1.000	1.000				
7							1.000	1.000	0.956			
8								1.000	0.921	1.000		
9									0.912	1.000	1.000	
10										1.000	1.000	0.936

Base 13

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.910	0.948	1.000									
2		0.941	1.000	0.942								
3			1.000	0.915	0.905							
4				0.918	0.916	0.929						
5					0.858	0.909	0.925					
6						0.863	0.923	0.974				
7							0.924	0.974	0.887			
8								0.958	0.875	0.932		
9									0.882	0.945	0.965	
10										0.945	0.965	0.964

Base 14

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.924	0.979	1.000									
2		0.978	1.000	0.982								
3			0.984	0.957	1.000							
4				0.964	1.000	1.000						
5					0.994	1.000	1.000					
6						1.000	1.000	1.000				
7							1.000	1.000	1.000			
8								1.000	0.989	1.000		
9									1.000	1.000	1.000	
10										1.000	1.000	1.000

Base 15

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.850	0.887	0.882									
2		0.885	0.875	0.872								
3			0.867	0.871	0.827							
4				0.853	0.816	0.895						
5					0.814	0.884	0.882					
6						0.808	0.801	0.769				
7							0.801	0.770	0.846			
8								0.762	0.842	0.856		
9									0.893	0.906	0.881	
10										0.906	0.881	0.884

Base 16

Anal-ysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.940	0.936	1.000									
2		0.935	1.000	1.000								
3			1.000	1.000	0.903							
4				1.000	0.903	1.000						
5					0.921	1.000	1.000					
6						1.000	1.000	1.000				
7							1.000	1.000	1.000			
8								0.988	1.000	1.000		
9									1.000	1.000	0.965	
10										1.000	0.964	1.000

Base 17

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	1.000	1.000	1.000									
2		1.000	1.000	1.000								
3			0.999	1.000	1.000							
4				0.990	0.987	1.000						
5					0.986	1.000	1.000					
6						1.000	0.996	1.000				
7							0.996	1.000	1.000			
8								1.000	1.000	1.000		
9									1.000	1.000	1.000	
10										1.000	1.000	1.000

Base 18

Analysis	Quarter 1	2	3	4	5	6	7	8	9	10	11	12
1	0.995	1.000	1.000									
2		0.999	1.000	1.000								
3			1.000	0.972	1.000							
4				0.973	1.000	0.952						
5					1.000	0.945	0.999					
6						1.000	1.000	1.000				
7							1.000	1.000	1.000			
8								1.000	1.000	0.978		
9									1.000	0.980	1.000	
10										1.000	1.000	1.000

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Assistant Professor of Quantitative Methods

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The objective of this research was to measure the productivity of the Tactical Air Command's (TAC) Accounting and Finance Offices (AFOs) for calendar years 1983-1985. Two separate approaches, both using a methodology called Data Envelopment Analysis (DEA) as their base, were used to measure productivity changes over this period. Both approaches (window analyses and program versus managerial efficiency) used a two input, seven output DEA model for the analyses.

The window analyses approach is analogous to smoothing techniques used in econometrics and involved subdividing the annual data into quarterly data and creating moving windows consisting of three quarters of data for each AFO. The first three quarters of data were initially evaluated for all 18 AFOs and then subsequent analyses were performed by dropping the first quarter's data and adding the next (fourth quarter's data). This process of dropping and adding quarterly data was continued until each group of three quarters of data were analyzed, forming a moving "window" of each quarter so that changes over time could be detected.

The program versus managerial approach eliminated managerial inefficiencies for each year and then compared each year's activity (=program) for productivity changes that were programmatic. To implement this approach each year's data were treated as a unique program and analyzed separately using DEA. The DEA results were then used to "adjust" the AFOs found to be inefficient, resulting in all units for that year becoming efficient. All three programs were then analyzed together using the DEA model. These results were then reviewed for shifts in productivity between program (years).

Productivity changes were checked through the use of regression analyses. Even though each approach showed signs of productivity increases, the corresponding statistical tests failed to provide conclusive evidence to support an actual increase during this period.

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